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APPLICATION OF LANDSAT IMAGERY IN LAND USE INVENTORY
AND CLASSIFICATION IN NEBRASKA

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Marvin P. Carlson and Paul M. Seevers
Conservation and Survey Division
University of Nebraska-Lincoln
Lincoln, Nebraska 68688 *etc*

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16. Abstract The purpose of this contract was to further refine the land use inventory systems from Landsat imagery. The investigation was designed to involve action agencies in projects which derived current and accurate data from satellite imagery. Specific projects included land use inventory, lake-level monitoring, irrigated lands inventory, wetlands inventory, and location of center-pivot irrigation systems. Problems were encountered in image resolution and automatic interpretations tied to legal grid-cell locations. In addition to the project achievements, the credibility of satellite imagery as a data source has been established within the planning and management organizations.			
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PREFACE

The major objective of this investigation was to evaluate the practical utilization of satellite imagery in terms of both the validity of the data acquired and its acceptance by a user audience. Two principal parameters limited the scope of the investigation; firstly, the relatively low resolution of the Landsat imagery and, secondly, little motivation for the various regulatory/planning agencies to place a priority upon acquiring land use data. Both of these parameters are evolving in ways which could greatly enhance the results of the investigation. A major achievement has been the establishing of the credibility of remotely sensed data from satellites and the creation of an acceptance of this data by decision-makers.

The proposed approach to the investigation was to further refine the classification systems and to attempt automatic extraction of data from imagery. It was thus anticipated that specific applications could be created which would become ongoing programs for appropriate agencies and organizations. As is apparent from the pilot projects, a variety of categories and inventories can be extracted from Landsat imagery. However, it was discovered that nearly all users require that the data be identified by legal location for integration with other considerations. This requirement greatly increases the time and effort involved in most inventories and exceeded the capabilities of our systems for automatic data extraction.

The investigation did achieve the objective of coordinating the utilization of Landsat imagery within Nebraska. Several pilot

projects were carried out and, in varying degrees, most of them are continuing to evolve into direct applications. Whenever possible the projects included publication of the data in a format designed to attract further attention from potential users. The limitations discussed prohibit ongoing automatic extraction of data from current imagery. However, a climate has been created and an operational framework established which will continue to evolve toward this type of program.

OBJECTIVES

The purpose of this investigation was to further examine the application of satellite imagery in the problems of land use inventory. More intensive use of the available resources is placing stress upon the environment and causing concern about the proper role of the various regulatory/planning agencies. The problems being created can only be understood if current and accurate data are available. It is anticipated that remote sensing techniques will play a large part in assembling these data in a cost-effective manner. The sequential, multi-spectral imagery provided by Landsat was utilized for evaluation of potential applications of remote sensing.

The investigation was designed to involve a variety of state and local agencies and, whenever possible, expand upon their current programs. These projects were particularly oriented toward those agencies with natural resource responsibilities. The economic base of Nebraska is closely tied to its agricultural activities which in turn are dependent upon its soil and water resources. As these resources are developed, stress is placed upon the natural resource systems and long range commitments are made for continuation of certain types of land use activities. The impact of development needs to be monitored to properly plan and manage for the benefit of both our current and future society.

The entire state of Nebraska was included in the investigation. Political considerations require that any potential land use programs have some degree of coordination at the state

level. It was anticipated that the gross consistency of physiographic, climatic and geologic factors within Nebraska would allow an optimum evaluation of cultural factors. This proved to be true and will be a major advantage as coordinating systems for utilization of the resources continue to evolve. Major efforts are being made to complete various data bases such as the 7½ topographic quadrangles, bedrock geologic maps, aquifer delineation and the individual county soils maps.

Changes imposed upon these data bases can be monitored by remote sensing from satellite. However, for most activities, Landsat imagery lacks sufficient resolution for practical application. Several projects, such as the center-pivot system inventory, were immediately successful and accepted. In other cases, the techniques could be demonstrated but failed to attract support for ongoing utilization. In addition to the problem of category resolution, inventory by legal subdivision was difficult. Nearly all land use data are tied to this system. Any ongoing program in Nebraska of data extraction from satellite imagery will need the capability of interfacing with the section/township/range system of location.

Aircraft imagery and ground truth data collection were scheduled to be used as training aids in developing techniques for automatic extraction of equivalent data from satellite imagery. This proved to be a valuable learning process during the investigation. Techniques for image enhancement appeared to fall into two classes: simple methods of doing scale change, image projection, color composites and density slicing and com-

plex methods requiring equipment and expertise far exceeding the level of this investigation. Because of these data-handling limitations, most of the projects utilized either the 70 mm or 9-inch by 9-inch transparency as an imagery data source. Computer compatible tapes offer much more potential for automatic data extraction but proved to be beyond the scope of most projects within this investigation. Any remote sensing techniques designed for applications projects and transfer to action agencies must consider the level of expertise and automation which will be acceptable for ongoing program.

A final objective of the investigation was to develop coordination and communication among the various groups in the user-audience. Acceptance of remotely sensed data will depend upon the credibility of the data as evidenced by its availability, by the interpretive procedures possible, and by the distribution of useable products. As some of the limitations of the investigation became apparent, greater emphasis was placed upon maintaining this basis of credibility. This may well prove to be the most noteworthy achievement of the investigation as application procedures for the utilization of satellite data continue to evolve.

ORGANIZATION

The investigation as proposed had six co-investigators representing as many state agencies each with a vested interest in land use data. Rather than focus on a specific research project which might not have application or implication for all investigators, it was decided to interface interpretation from Landsat imagery with ongoing programs wherever possible. The new program needs of the various agencies would be evaluated to anticipate any potential utilization of satellite data. The investigation funds were utilized, for the most part, to support a coordinator whose responsibility was to both maintain an awareness of land use program activity and to keep informed of current Landsat research at all levels. This proved to be satisfactory in conducting a very broad-based investigation with limited resources.

Activities of the investigation were located within the Remote Sensing Center at the University of Nebraska-Lincoln. This allowed access to staff expertise, data, equipment and provided technical and clerical support. The information acquired during the investigation could also be immediately incorporated into and distributed through the ongoing system. There were also a number of ongoing projects being conducted by the Center and its parent organization, the Conservation and Survey Division. The Division, as the natural resource data agency for the state, is a focus for research and service activity for all areas of government, industry, and private concerns.

The intent of this investigation was to explore new research techniques for extracting land use data from satellite imagery. The program emphasis was on research beyond the support provided by other areas for known applications. Thus, some of the projects largely supported by other agencies and industry could be carried beyond the immediate application phase. This potential was particularly important when dealing with imagery, such as Landsat, which had limited resolution. Although acceptable products might not be generated on an ongoing basis, techniques and procedures could be developed which could be quickly adopted for new data sources. This approach is particularly important when continuing remote sensing programs are being established with action agencies. Current capabilities should not be oversold to the detriment of future utilization. During the investigation specific co-investigators were reassigned, but the agency coordination was maintained and the validity of satellite imagery as a data source has been further strengthened.

DATA ACQUISITION

Landsat

As a part of the contract, Landsat 2 imagery for Nebraska was obtained as 9 inch by 9 inch positive transparencies. A standing order was maintained for Band 7 up to 90 percent cloud cover for image reference. A standing order for Bands 4, 5, and 6 was maintained with cloud cover varying seasonally up to 40 percent. Minimum image quality of 8 was required.

Upon receipt from EROS Data Center, imagery was verified and placed in glassine envelopes. Each item is indexed by the path/row index system of the Nebraska Remote Sensing Center and filed. New data is integrated by computer entry into the monthly update of the Remote Sensing Center reference catalog. This catalog system also contains enhanced image products, Landsat 1 imagery and any special order Landsat imagery.

Computer compatible tapes of Landsat image for the test site in north central Nebraska was received and entered into the catalog system. A Digital Image Rectification System (DIRS) was received on loan but has not yet been brought online for CCT interpretation. However, printouts for visual interpretation have been generated from the CCT.

Aerial Photography

Seasonal photography of the Upper Niobrara-White and the Lower Niobrara Natural Resources Districts was provided by NASA Houston and NASA Ames. A RB-57 mission on 16 May 1975 supplied color infrared film at a scale of 1:120,000 for both NRD's. On 26 September 1975, a U-2 mission provided color infrared photo-

graphy at a scale of 1:130,000 for the Upper Niobrara-White NRD. A P-3 mission on 25 and 26 September 1975 furnished color infrared photography at a scale of 1:50,000 for the Lower Niobrara NRD. The fall missions were nearly 30 days past the desired cropping "window" and are marginal data.

Upon receipt, the photography is cut into 9 inch by 9 inch frames and placed in glassine envelopes. The frame number, date, and Natural Resource District is noted on each item. Each frame is plotted and identified on a 1:250,000 U.S. Geological Survey topographic map. The Remote Sensing Center is Nebraska's representative in the network for the National Cartographic Information Center's Aerial Photography Summary Record System.

GENERAL PROJECTS

A major effort of the contract was the daily activity carried on in association with the ongoing functions of the Remote Sensing Center. Concerns, problems and potential projects were often first identified through the Center. In addition to the cooperative projects with state agencies, educational efforts related to Landsat imagery were also carried out. An example is a display created within the State Museum consisting of the 1:1,000,000 Landsat image of the United States. Appropriate examples of image utilization are included with the exhibit. Workshops were held for key staff of agencies to acquaint them with the potential applications of satellite imagery.

Personnel of the Nebraska Department of Water Resources spent several man-days evaluating the use of Landsat imagery for identification of sediment load in streams throughout the state. It was found that Landsat data did not have sufficient resolution to adequately identify sediment loads. A similar evaluation was performed by staff of the Nebraska Department of Roads. Landsat imagery was compared to aerial photography currently utilized for systematic review of road conditions. Again the potential application exists but current satellite resolution is inadequate.

The Remote Sensing Center has had a number of requests from agribusiness firms throughout the state for photographic enlargements of Landsat imagery. The imagery provides a highly visible display of irrigation development by selecting band 5 images in late July or August for the desired year. There is maximum con-

trast at that time between irrigated and non-irrigated crop and rangeland. Visits with users of the imagery have indicated the enlargements to be highly effective visual aid in their presentations. These types of relatively low-key activities will provide support for more specific research in the future.

LAND USE INVENTORY PROJECT

Goals

One of the more important research projects designed as a part of this investigation was the further definition of land use categories which could be derived from Landsat imagery and the determination of the feasibility of automated extraction of categories. Within the Remote Sensing Center, there are ongoing Level II land use inventory programs for selected areas supported by action agencies. These inventories are based on 26 categories and are usually a ten-acre, legal grid. Seasonal, color infrared aerial photography is the standard data source. It was anticipated that, for at least portions of Nebraska, somewhat similar data could be derived from Landsat imagery.

Data Utilized

High altitude aircraft color infrared coverage of two Natural Resource Districts utilized as test sites were provided by NASA Houston and NASA Ames in late 1975. Equipment problems within NASA lowered the quality of the photography. Ground truth collected by University of Nebraska Remote Sensing Center personnel were acquired in conjunction with the aircraft flights. Landsat data of suitable quality and cloud cover were acquired on a routine basis from the EROS Data Center. Both 9 inch by 9 inch positive transparencies and computer compatible tapes were utilized.

Procedure

Established methods for Level II inventory were carried out for the two test areas to establish a data base. The data is

initially recorded on a standard form (attached) and entered into computer storage. Programs have been devised and refined to manipulate and display the inventory data for various users and to accelerate the publication process of map products.

Computer compatible tape data from Landsat scenes which come the nearest to the aircraft flight dates were examined to establish the potential for extraction of equivalent data. Attempts were made to bring the Digital Image Rectification System (DIRS) package on line for automated evaluation of CCT. The complexity and incompleteness of documentation has not yet allowed successful utilization of this approach. However, using landmarks recognizable on printer output of CCT, an initial evaluation was conducted for identification of row crop.

A pilot study was conducted for a selected area to directly extract land use from the 9 inch by 9 inch Landsat positive transparencies. Each scene (in Band 5 and Band 7) was cut into 16 chips and mounted as slides for projection through a 70 mm projector. The original 1:1,000,000 scale was enlarged onto a frosted-glass, rear projection screen and interpretation made directly on base maps at a scale of 1 inch equals 2 miles. Level I categories have been mapped. Additional evaluation is being made to determine the feasibility of Level II modification and the utilization of Landsat color composites.

Results

Level II land use inventory has been completed and the data computerized for the Lower Niobrara Natural Resources District. The inventory for the Upper Niobrara-White Natural Resources Dis-

COUNTY _____ IMAGERY _____ DATE _____

SEC _____ TWN _____ N RNG _____ E/W _____ INTERPRETER _____ DATE _____

	A	B	C	D	E	F	G	H
1								
2								
3								
4								
5								
6								
7								
8								

1. URBAN

A-Residential
B-Commercial
C-Industrial
D-Transportation
E-Institutional
F-Recreational
G-Strip & Clustered

H-Mixed

I-Open & Other

2. AGRICULTURAL

J-Row Crop
K-Small Grain
L-Pasture
M-Fallow
N-Horticultural

O-Farmstead

P-Feeding Operation
Q-Other

3. RANGELAND

R-Rangeland
4. FOREST LAND
S-Deciduous
T-Evergreen

5. WATER

U-Streams
V-Lakes
W-Reservoirs
X-Other

6. NONFORESTED WETLAND

Y-Nonforested Wetland

7. BARREN LAND

Z-Barren Land
θ-Extractive

-12-

_____ Terraced

△ House

□ Farmstead

trict is over 90 percent complete. These data are released as soon as available to any interested user. Selected areas within these Districts exhibiting varying complexity of land use are being utilized as "ground truth" for evaluation of the Landsat data.

Technical problems have forestalled the automated extraction of data from the computer compatible tapes. However, manual interpretation has shown that radiance values in Band 5 for row crops in May of 1975 were at least double the value of row crop radiance values in September, 1975. This range of values within a single category during a cropping season is encouraging. Multitemporal differences are the basis for several category definitions from aerial photography. Many areas of Nebraska have rather simple land use patterns even at Level II. The initial correlation of radiance values strongly suggests that these patterns will be apparent on CCT and, thus, susceptible to automatic extraction if the technical system problems can be resolved.

The pilot projects which established the technique of enlargement and rear screen projection of Band 5 and 7 achieved over 90 percent accuracy in selected areas. A full-scale test evaluation of this technique was carried out by Basin Electric Cooperative for the routing of a 350 mile-long power line. Approximately 25,000 square miles was mapped, using untrained personnel, at a cost of 37 cents per square mile and maintaining over a 90 percent accuracy. This cost included labor, supplies, equipment and Landsat Band 5, Band 7, and color composites. The categories desired for this project were Level I modified to dif-

ferentiate grazed land from harvested forage. A comparable alternative method of data extraction from Landsat was estimated at \$3.20 per square mile. This technique should prove to be highly applicable for Nebraska and similar states which have large areas of low intensity land use.

SAND HILLS LAKE MONITORING PROJECT

Goals

Observation well data have shown water tables to be permanently lowered by varying amounts, presumably due to irrigation development, in several areas of the state. Concern has been expressed as to the effect of development of irrigation on the lakes and wetlands of the Sand Hills. It is assumed that these lakes are a surface expression of the water table in the Sand Hills. Monitoring of lakes for permanent decrease in area then would reflect changes in the water table. Literature indicates that Landsat data can be used to accurately monitor the area of surface water. It was the intent of this project to investigate the use of Landsat data for monitoring the surface area changes in lakes of the Sand Hills.

Data Utilized

Landsat imagery in the form of 9 inch by 9 inch positive transparencies was available, from August 1972 to the most recent, in the Remote Sensing imagery library. One computer compatible tape (CCT) was also available for the test site to provide data for the lakes. Additionally, high altitude aircraft color infrared photography, flown by NASA Ames was available for the test site. Each data source provided a specific level of precision of measurement and a comparison of accuracy.

Procedure

Photographic enlargements (10x) of the lakes being studied were made from file copies of Band 7, 9 inch by 9 inch positive transparencies. Outlines of the lakes were traced on a matte

mylar overlay and a dot grid was used to measure the areas.

Three dates of imagery were selected for evaluation for each year; pre-irrigation, during peak irrigation and post-irrigation

Aerial photography for a pre-irrigation and post-irrigation date were available for the test site. Dot grid measurements were made directly from the photographs.

Printer displays of CCT data for band 7 were made for the pre-irrigation date available. A pixel count was made for each lake studied and the area in acres, calculated by multiplying pixel count by 1.1. Lakes S15 and S24 are outlined on the sample print out.

Results

Table 1 shows the surface acres measured by the techniques and data sources for four lakes selected in Sheridan County, Nebraska. Assuming the aerial photography provides the most accurate measurement of surface area of the lakes, CCT data provide the most accurate Landsat data source to measure surface area. Because of the enlarging procedure and the lack of sharply defined lake boundaries, the transparencies showed the greatest variation in measurements.

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Table 1: Surface Acres of Water for Selected Lakes in the Sand Hills of Nebraska

Lake	S15	S24	Joe	Bennet
Dot Grid Count				
Aerial Photography				
16 May 1975	68	141	103	86
26 Sep 1975	63	112	106	28
Landsat, Band 7				
15 May 1973	44	127	82	85
13 Aug 1973	49	127	100	57
6 Oct 1973	43	124	93	63
28 May 1974	66	157	120	109
22 Jul 1974	53	119	101	78
19 Oct 1974	33	104	103	27
20 Jun 1975	61	150	117	95
26 Jul 1975	54	143	109	82
6 Oct 1975	51	113	115	17
27 May 1976	68	137	115	98
25 Aug 1976	51	141	120	53
9 Oct 1976	45	104	109	22
Pixel Count, Band 7				
Landsat Imagery				
19 Jun 1975	66	143	102	80

Examination of the transparency data for the four available years shows that the procedure is sufficiently accurate to reflect surface area changes within one growing season. The data also show that pre-irrigation levels appear to be relatively constant from year to year. Examination of rainfall data for the area would suggest that the year to year variation may be a response to precipitation levels. Technique error, however, is similar in magnitude to the variability seen in the year to year data, so further evaluation is necessary to firmly establish trends in change of surface area of the lakes.

The results to date indicate that Landsat data can be used to monitor change in surface area of the lakes examined. Additional efforts are being planned to collect ground truth and other data to further validate the technique. If this project demonstrates acceptable accuracy, satellite imagery can be a major tool in monitoring regional changes in the water table within the Sand Hills.

IRRIGATED LANDS INVENTORY PROJECT

Goals

It is estimated that about 6.3 million acres were under irrigation in Nebraska by the end of 1976, an increase of about 12% for the year. Nearly 55,000 irrigation wells serve to irrigate about 85% of this acreage, obviously a tremendous utilization of underground water supplies. The energy sources for these wells are: Diesel, 37%; electricity, 25%; natural gas, 23%; LP-gas, 14%; and gasoline, 1%. These data indicate the importance of monitoring the irrigation activity in Nebraska. This activity impacts the state in many ways: economic factors, environmental changes, quantity and quality of water supplies, energy demand, plus others less obvious. Several pilot projects have been carried out in cooperation with the Remote Sensing Center to assess potential monitoring systems related to Landsat imagery.

Data Utilized

The principal data utilized in these projects has been seasonal Landsat imagery. All four bands were used in varying combinations with the data being compiled on Band 5 positives enlarged to 1:125,000. Field checking was, of course, a required method of data evaluation. Other available information included: partial coverage by color infrared aerial photography, surveys conducted by the ASCS (Agricultural Stabilization and Conservation Service), and registered irrigation wells and surface water rights. Cooperating agencies were the Nebraska Natural Resources Commission, Nebraska Department of Water Resources, State Office of Planning and Programming and local Natural Resources Districts.

Procedure

False color composites were made from Bands 4, 5 and 6 positive Landsat imagery obtained from NASA at a scale of 1:1,000,000. Separate diazochromes (yellow, magenta and cyan for Bands 4, 5 and 6) were prepared by about 6 minutes exposure to ultraviolet light and then ammonia development. Black and white positive images of Bands 5 and 7 were also used separately.

A high quality overhead projector was used to project the black and white positive images and false color composites onto a screen at a scale of 1:250,000. A grid pattern representing square mile patterns, on transparent mylar, was overlaid on positive prints of Band 5. The transparencies were projected in varying sequences to prepare overlays for each category. A density slicer was used to determine the percentage of each category within the mapped area.

Results

The following were determined to be the optimal utilization of Landsat imagery for the categories selected:

<u>Category</u>	<u>Black & White Imagery</u>		<u>Color Composite</u>
	<u>Date</u>	<u>Band</u>	<u>Date</u>
Alfalfa	Early May	7	Early May
Irrigated Row Crops	July or August	5	July or August
Dryland Row Crops	July or August	5	July or August
Small Grain	May and July	5	May and July
Range or Pasture	May to August	5	May and July
Urban and Built-up	July or August	5	July or August
Open Water	Any date	7	Any date

The 1:250,000 scale was the largest which seemed appropriate for utilization of enlarged Landsat imagery. Two, eight-color county maps were published at a scale of 1:125,000. Copies of

the various inventories were furnished to appropriate agencies. It is estimated that an interpreter, familiar with cropping patterns and utilizing available data on file, can compile a Landsat-based inventory approaching 90 percent accuracy through a density slicing determination of the ratio of irrigated land in a mapped area. Although this technique is a valid utilization of satellite data, pressure for this type of data from responsible agencies has not yet caused ongoing application of the procedure.

WETLANDS INVENTORY PROJECT

Goals

At the time the contract was initiated, an inventory project was underway in cooperation with the Nebraska Game and Parks Commission. There are an estimated 17,000 wetlands within Nebraska. These are defined as areas having surficial water, or perennial or seasonal excess water, acting as a major influence on plant communities. Nebraska's wetlands, which are a key element in waterfowl migration and population, have been subject to reduction by agricultural and urban development for the last several decades.

Funding and time constraints for the project prohibited inventory by direct methods. Furthermore, the majority of wetlands occur in the sandhills region of Nebraska. This area of approximately 20,000 square miles has few roads and ground inventory would be very difficult. It was decided to utilize Landsat imagery and document the success of classification by satellite imagery.

Data Utilized

High altitude aircraft color infrared photography (1:125,000) was available for limited areas. This data plus older soils maps and small scale topographic maps provided some measure of ground truth for the interpreter. Positive print enlargements of Landsat imagery at a scale of 1:250,000 and electronic image enhancement were utilized for basic data interpretation.

Specific imagery used were Band 5 and Band 7 acquired in spring or early summer and Band 6 and Band 7 acquired in late

summer or fall. The definitions used for the inventory were:
Open Water - areas, ten acres or larger, persistently covered by water.

Subirrigated Meadows - low-lying areas, not irrigated by man, in which plant roots extend to the water table.

Marshes - areas of emergent aquatic vegetation commonly intermixed with small areas of open water.

Seasonally Flooded Basins - low-lying areas in which water periodically collects and floods the surface.

Procedure

Positive print enlargements at a scale of 1:250,000 were prepared for the selected imagery. Transparent overlays were used to record the areas covered by the appropriate categories. Open water appears as black on all Band 5 and Band 7. (Some exceptions can occur in areas of unique water quality). Subirrigated meadows appear dark gray to black on Band 5 but very light on Band 7. Cropping and growth patterns will distinguish meadows from agricultural land.

Marshes have characteristics similar to open water under visual interpretation. Image-enhancing systems were used to enlarge late summer, Band 6 to approximately 1:60,000. At this scale, marshes have an obvious mottled greytone compared with the black and dark gray of open water. Seasonally flooded basins were mapped by using Band 7 from spring and late summer. This category must also be defined by a general knowledge of water table conditions as well as the influence of man-made variations in surface water storage.

Results

It was possible, using Landsat imagery, to inventory wetlands ten acres or larger in size with an average accuracy of 85 percent. A relatively simple, visual interpretation was utilized which required about two man/months. It was determined that 97 percent of Nebraska's wetlands occur in two areas, the sandhills containing about 17,000 wetlands and south-central Nebraska containing about 4,000. The inventory data were recorded in stable-base map format to provide the Nebraska Game and Parks Commission with a permanent record.

A set of four-color maps at a scale of 1:250,000 was published covering the three portions of Nebraska containing most of the recorded wetlands. General distribution of these maps have provided a perspective for farmers, hunters and regional planners. This inventory has also been used as background for more local studies involving wetland drainage and wildlife refuge areas.

CENTERPIVOT SYSTEM INVENTORY PROJECT

Goals

It is estimated that about 28% of Nebraska's 6.3 million irrigated acres is accomplished through the use of center-pivot systems. However, over 80% of the current increase in irrigation is due to the installation of these systems. Irrigated agriculture has become the stabilizing factor for the economic base of Nebraska. The center-pivot type of system is accelerating both the benefits and concerns about the future of irrigation.

An average center-pivot will cover about 133 acres, often in areas where the land surface is not amenable to other types of irrigation. These systems use an estimated 53.4 gallons of Diesel fuel or equivalent per acre-year and distribute about 407,560 gallons of water per acre-year. There are obvious economic, environmental, energy and resource concerns about this expanding activity. Many agencies and organizations require a current and accurate inventory of these center-pivot irrigation systems.

Data Utilized

Both the circular pattern and the actively growing irrigated crops create a contrasting characteristic for these center-pivot irrigation systems on Landsat Band 5. The U.S. Geological Survey 1:250,000 topographic maps are used as a base for determination of legal locations.

Procedure

An optical system is utilized to magnify, align and transpose the Band 5 and the base map onto a stable base. Currently

a Zoom Transfer Scope is being utilized and proven satisfactory. When the data are correctly oriented, a small circle is drawn to mark each center-pivot system. Once the initial inventory is compiled, a comparison of the plotted data with several Band 5 images during the current growing season allows a rapid update.

Results

It is possible to inventory the center-pivot systems from Landsat Band 5 for Nebraska in about 150 man/hours. A comparison with available infrared aerial photography and ground checks suggests an accuracy of about 95%. Support from other interested agencies have allowed this research technique to become operational within the Remote Sensing Center. The inventory data are entered into a computer-oriented, storage-retrieval system. Data can be provided in tabular format or in a variety of time/area map formats. The original 1975 inventory and a 1976 update have been published as five-color, 1:1,000,000 state maps of center-pivot locations and tables summarizing annual installation by county. These data provide appropriate agencies with an indication of changing economic, land use, water utilization and energy demands.

FOLLOW-ON PROGRAM

The support provided by this contrast has allowed the initiation of a variety of pilot projects in conjunction with action agencies. Sufficient interest and supplemental funding was generated to allow the continuation of similar activity for at least the current fiscal year. However, there is not expected to be inhouse expansion of staff or enhancement equipment based upon satellite imagery of Landsat quality.

The imagery library will be continued although standing orders for Landsat data have been discontinued. Cost factors and the availability of microfilm readers have altered the data aquisition program. Representative, seasonal imagery in the 9 inch by 9 inch format will be purchased as well as specific project material. The reference catalog will be continued.

Both state and local action agencies continue to test and evaluate Landsat data for specific projects. They are aware of the limitations but continue to consider satellite imagery as a potential tool. The Natural Resources Commission, as the lead agency for the 208 water quality program, has evaluated satellite imagery for land-erosion characteristics, for sediment dispersal and for irrigation potential. The Game and Parks Commission has reviewed imagery to define migratory bird habitat and potential refuge areas. The Department of Water Resources has monitored large active streams. None of these evaluations have resulted in significant ongoing projects. In most cases the action agencies have had to resort to available photography or special data gathering efforts. However, the awareness of the potential for satellite imagery has been created.

The Center-Pivot Inventory will continue to be published annually by the Remote Sensing Center. Regulatory agencies, such as the Department of Water Resources and Natural Resources Districts, are utilizing these inventories in conjunction with irrigation well registrations to monitor groundwater utilization. The Land Use Inventory, where available, also supplements this program. The Game and Parks Commission and the Department of Water Resources are particularly interested in the ongoing Sand Hills Lake Monitoring. This activity may become a part of a major cooperative water resources investigation program by the Conservation and Survey Division and the U.S. Geological Survey.

The coordinating role of the Remote Sensing Center is strongly supported in principle by the State Office of Planning and Programming. This identity by state agencies and the research image provided through the University should continue an active program for the utilization of remote sensing in Nebraska.